Assessment of the Southern Ocean solution in the ECCO2 data syntheses

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Motivation:

The ECCO2 data syntheses uses most available global-scale ocean and sea-ice data to obtain a best possible estimate of the ocean circulation (Fig. 1). Global ocean circulation models do not usually take high latitude processes into account in an adequate form. In order to assess what processes are missing, how these processes can be parametrized, or what additional data need to be assimilated in the ECCO2 data syntheses, two model solutions (an optimized solution – OPT and a baseline experiment with enhanced evaporation in the Southern Ocean) were analysed. A focus was placed on the Weddell Sea (Fig. 2) as it is an important region for deep and bottom water formation contributing to the ventilation of the global ocean abyss.

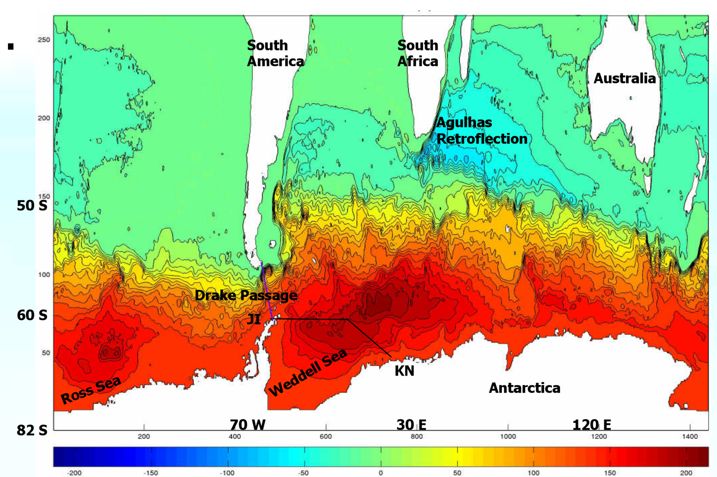


Fig. 2: Horizontal Streamfunction of the Southern Hemisphere depicting the Antarctic Circumpolar Current (ACC) Region with its subpolar gyres. Indicated are two sections: black - Kapp Norvegia (KN) to Joinville Island (JI), and blue - Drake Passage .

Model:

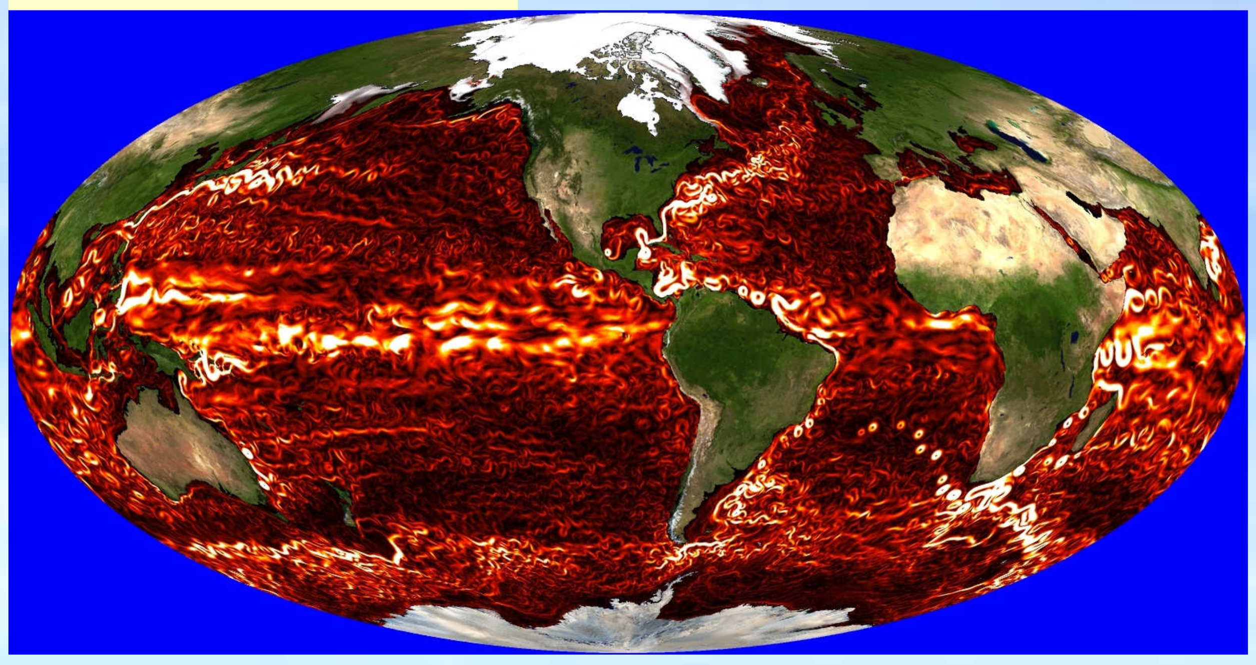


Fig. 1: High resolution global ocean circulation model ECCO2 (Estimating the Circulation and Climate of the Ocean, Phase II: High-Resolution Global-Ocean and Sea-Ice Data Synthesis). Syntheses of all available global-scale ocean and sea-ice data at resolutions that start to resolve ocean eddies and other narrow current systems, which transport heat, carbon, and other properties within the ocean

- based on MITgcm
- 18 km global resolution, 50 vertical layers
- 15 yrs integration (1992 to 2006)
- Run with optimised surface forcing (**OPT**)
- Run with enhanced evaporation in the Southern Ocean (**Base**)

Transports:

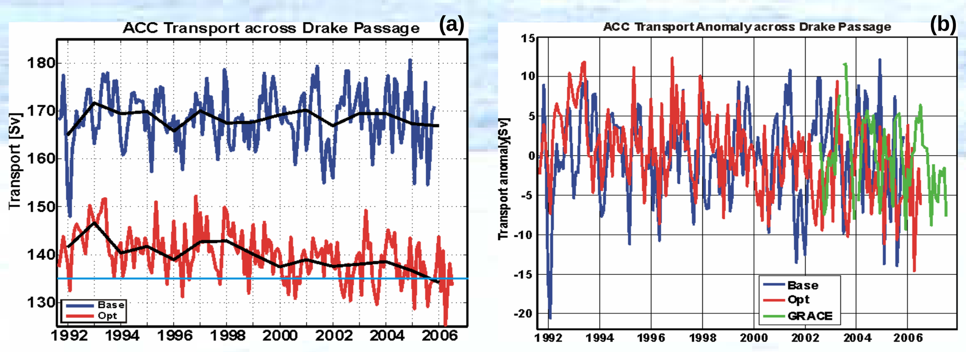


Fig. 3: (a) Volume transport across Drake Passage (see Fig.1). Black lines indicate annual means, the light blue line estimates from Sloyan and Rintoul (2001). (b) ACC volume transport anomalies compared to Grace values (green line). Transports are in Sverdrup: 1 Sv = 1 · 10^6 km³ s^{-1}

- OPT Drake Passage transport (138 Sv) in agreement with estimates; Base values too high (Fig. 3)
- ACC anomaly comparable to GRACE
- Weddell Gyre: westward shift of centre from baseline to Opt, lower values
- Ross Gyre: developed in opt but less interannual variability (Fig. 4)
- OPT low overturning in Southern Ocean (Fig. 5), enhanced in Base
- disconnected bottom cell from South

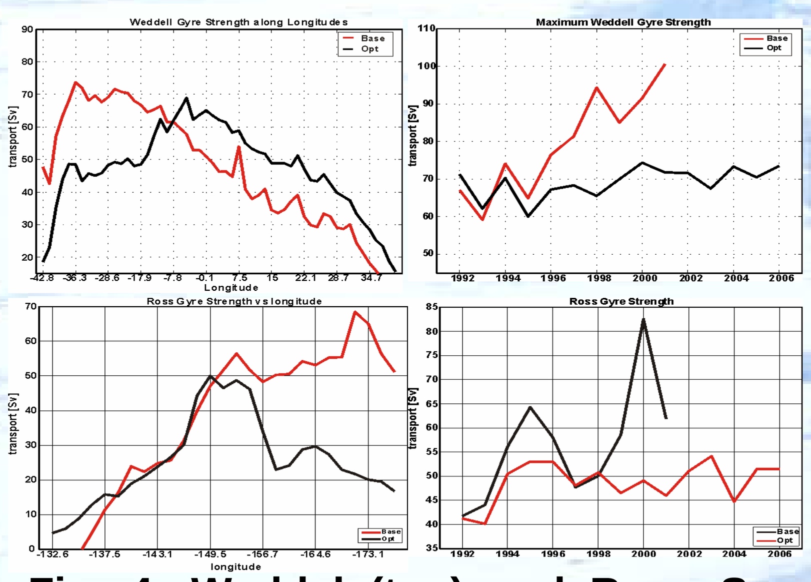


Fig. 4: Weddel (top) and Ross Sea (bottom) Gyre transports as time series for the integration period 1992 to 2006 (right) and as function of longitude (left).

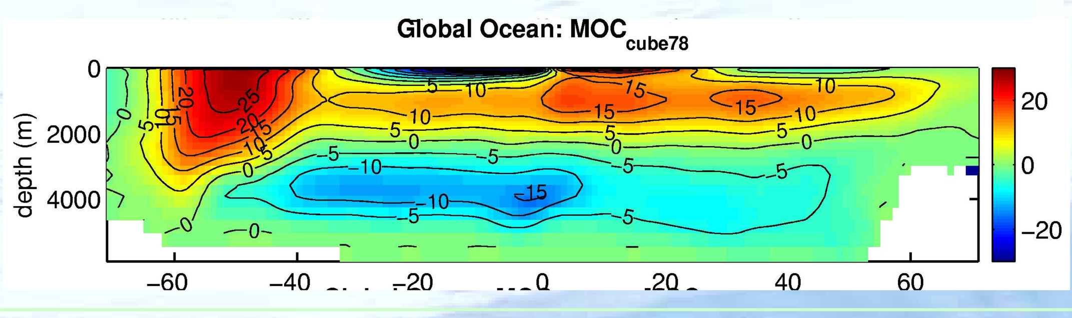
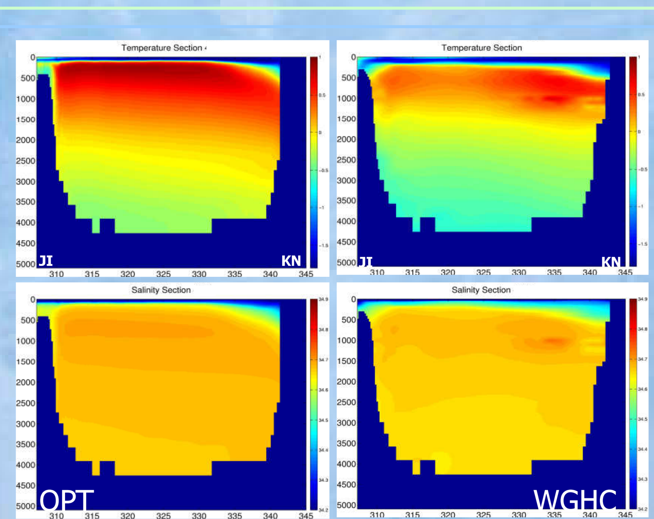


Fig. 5: Mean Meridional overturning circulation for the optimized solution (OPT).

Hydrography:

Fig. 10: Temperature (top) and salinity (bottom) section KN-JI. Left depicts the optimized solution (OPT) right the climatology (WGHC).



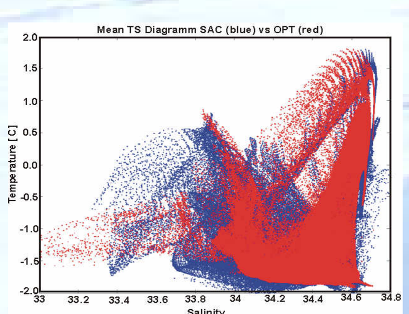


Fig. 9: Mean TS-Diagramm of the Weddell Sea (OPT – red, WGHC - blue)

- TS Diagramm shows: High Salinity Shelf Water is produced, water below the surface freezing point is not (Fig 9.).
- warming of water column -> warming of Warm Deep Water and less distinct features in the inflow region (east) and enhanced warming in the outflow region (west) of the Weddell Sea. (Fig. 10)
- bottom layer of the southern part of Drake Passage is warming by 0.11°C in 15 years
- northern part - higher interannual variability but no trend

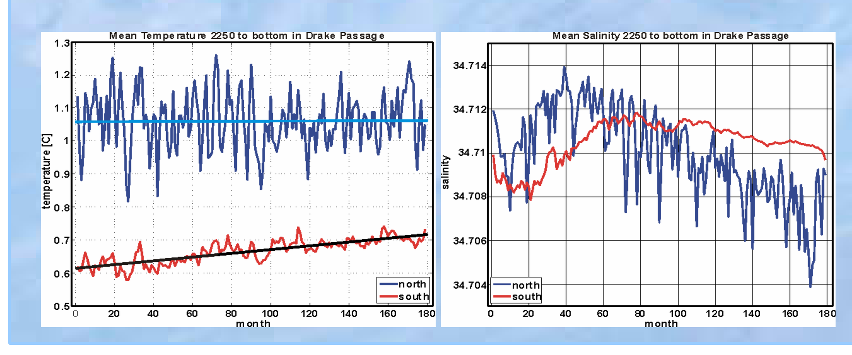


Fig.11: Time series of monthly mean temperature and salinity in the depth range of 2250 to bottom in Drake Passage. Blue curve depicts the northern part, red curve the southern part of Drake Passage

Sea Ice:

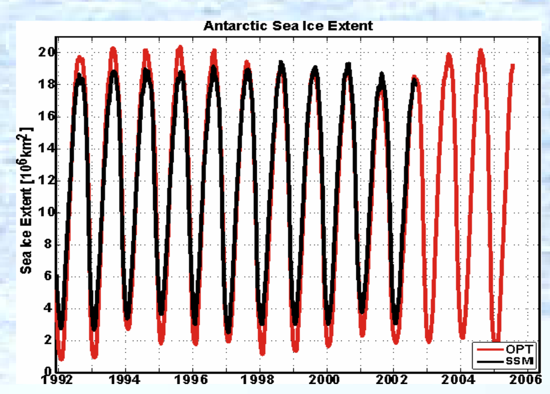
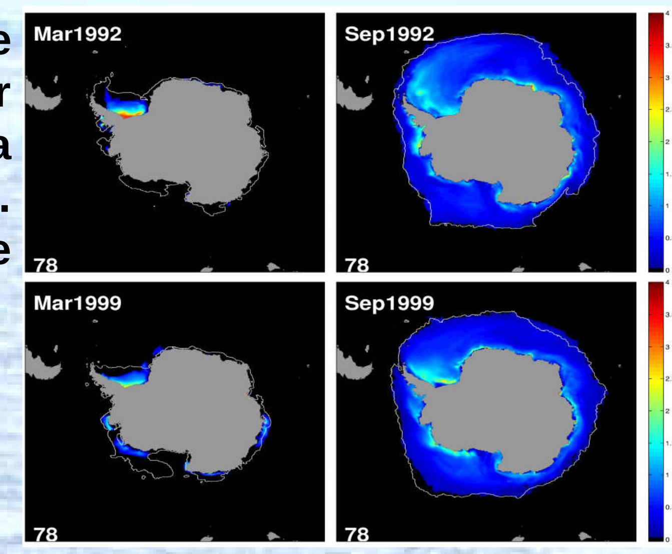


Fig. 7: Southern Ocean sea ice extent. OPT solution red, SSM/I data black

Fig. 6: Horizontal sea ice thickness distribution for maximum and minimum sea ice extend in 1992 and 1999. While line depicts the sea ice extent for SSM/I data.



- Summer sea ice extent underestimated compared to SSM/I data (Fig. 6)
- Winter sea ice extent overestimated in first 5 years, good agreement to SSM/I data thereafter (Fig. 7)
- Main differences in first 5 years winter sea ice extent occur in Pacific and Indian Sector of the Southern Ocean
- Sea ice volume transport in Weddell Sea matches estimates from observations (Fig. 8) - BUT:
  - → Sea ice speeds are too high
  - → Sea ice thicknesses are too low in coastal current (in- and outflow region)
  - → thinner sea ice thicknesses are more in agreement with observations than thicker modes

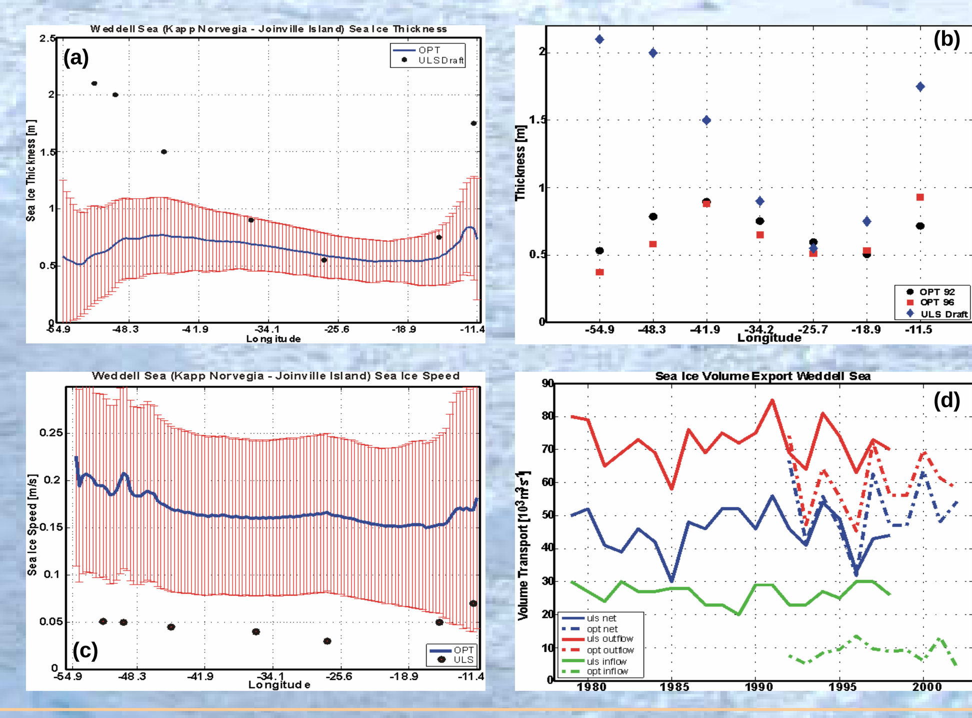


Fig. 8: Weddell Sea Ice thickness (A) along section Kapp Norvegia (KN) - Joinville Island (JI), at AWI-ULS Positions (B), sea ice speed along section KN-JI (c), and volume transport across the section KN-JI. Ice volume transport (D)

Conclusions and Outlook:

- Circulation and transport values are well represented in the model
- sea ice speeds are overestimated, summer thicknesses underestimated
- the water column is warming and getting more saline
- Overturning circulation underestimates the southern cell where deep and bottom water formation occurs

- Dense water masses are formed on the continental shelf but downslope flow is under represented -> need for parametrization
- Missing feature freshwater input from ice shelf ocean interaction will be implemented/parametrized
- → preliminary results from a model subdomain run show an increase in sea ice thickness in the western Weddell Sea by about 35 cm

References:

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